A Novel Non-Stationary Random Field Model and Its Application to Fill Slopes (Postprint)

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Abstract

To address the limitations of traditional linear non-stationary random field models in handling nonlinear variations of soil parameters in fill slopes, this paper proposes a non-stationary random field model that employs a piecewise linear function as the trend function. The coefficient calculation method, discretization procedures, and structured computational workflow of the improved model are elaborated in detail. The validity and applicability of the improved model are verified through comparative analysis of a loess fill slope case study. Additionally, since different discretization combinations of the non-stationary random field model exhibit variations in simulation accuracy and computational efficiency, this paper analyzes the effects of different discretization combinations on simulation performance. The results demonstrate that the piecewise linear non-stationary random field model exhibits stronger adaptability and higher fitting accuracy compared to the traditional linear model. At various burial depths of fill slope soils, the mean and standard deviation of soil property parameters simulated by the piecewise linear non-stationary random field model are significantly superior to those of the linear non-stationary random field model and closer to theoretical values. Regarding simulation accuracy: discretization combination 1 > discretization combination 2 > discretization combination 3; regarding computational efficiency: discretization combination 1 < discretization combination 2   discretization combination 3. When discretizing non-stationary random fields, appropriate discretization methods must be selected to enhance simulation accuracy and computational efficiency. Based on the aforementioned research, this paper recommends that discretization combination 2 be selected to achieve an optimal balance between simulation accuracy and computational efficiency, while discretization combination 1 can ensure high adaptability and precision of the model.

Full Text

Preamble

A New Nonstationary Random Field Model and Its Application to Fill Slopes

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Abstract

Conventional linear nonstationary random field models exhibit limitations in characterizing the nonlinear variation of soil parameters within fill slopes. To address this issue, this paper proposes an improved nonstationary random field model that utilizes a piecewise linear function as the trend function. The coefficient calculation methodology, discretization procedures, and structured computational framework of the proposed model are elaborated in detail. The model's validity and applicability are demonstrated through comparative analysis of a loess fill slope case study.

Additionally, since different discretization combinations for nonstationary random field models yield varying levels of simulation accuracy and computational efficiency, this study systematically examines the impact of various discretization schemes on modeling performance. The results indicate that the piecewise linear nonstationary random field model demonstrates superior adaptability and enhanced fitting accuracy compared to its traditional linear counterpart. Across different burial depths of fill slope soils, the model produces mean and standard deviation values for soil parameters that are markedly superior to those from the linear nonstationary random field model and more closely approximate theoretical values. Regarding simulation accuracy, the performance ranking is: Discretization Combination 1 > Discretization Combination 2 > Discretization Combination 3; for computational efficiency, the ranking is: Discretization Combination 1 < Discretization Combination 2 Discretization Combination 3.

The selection of an appropriate discretization method is crucial for optimizing both simulation accuracy and computational efficiency in nonstationary random field discretization. Based on these findings, this paper recommends Discretization Combination 2 as it achieves an optimal balance between accuracy and efficiency, while Discretization Combination 1 is recommended for applications requiring high adaptability and precision.

Keywords: fill slopes; soil parameters; trend function; nonstationary random field; mean and standard deviation